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Wet and Dry Analysis for the Cagayan Valley, the Philippines

Huynh Ngoc PHIEN* and Carlos C. TAN*

Abstract

In this first step toward a regional analysis of wet and dry events, the theory of runs is coupled with a multi-site data generation technique in order to serve two purposes. The first one is to define the parameters of the wet and dry events in terms of the runs-characteristics such as the run-length and run-sum, thus placing the wet and dry analysis within the scope of statistical and probabilistic treatment. The multi-site data generation scheme incorporates the inter-dependence (in space and time) between the data at various stations in a region into the analysis.

This approach is illustrated by a simulation study using the rainfall data at nine stations in the Cagayan Valley located in the Northern part of Luzon Island of the Philippines. The duration, magnitude and intensity of the wet and dry events are obtained for different demand levels.

I Introduction

Knowledge of the water condition in a region is of important interest to water resources planners. For one, the availability or unavailability of this vital resource can be predicted when adequate information is at hand. Consequently the amount of surpluses and deficits of rain water with their corresponding likelihood of occurrence can be estimated. Thus, irrigation can be appropriately scheduled for efficient and effective execution. Another, the extent of wet and dry conditions at different durations can be determined. Such information is very useful in the design of cropping patterns and planting schemes.

The analysis of wet and dry events has been carried out quite objectively by the use of the theory of runs since the work of Yevjevich [1967]. For the case when only one station is concerned, some important results have been obtained [Phien 1982; Phien and Vithana 1982; Sen 1976; 1977]. However, for a regional wet or dry analysis, there have been no suitable variables which represent the characteristics of wet and dry events satisfactorily. Because of this fact, the present study employs the theory of runs along with a multi-site data generation scheme in the wet and dry analysis for a region. The characteristics of runs, namely, the run-lengths and run-sums are used to define the wet and dry characteristics, while the multi-site scheme incorporates the correlation between data at all stations concerned into generated sequences.

The proposed technique is applied to the case of nine rainfall stations in the Cagayan

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Valley, Luzon Island, of the Philippines. Although for actual practices, a daily basis would be preferred, a monthly frame was adopted instead because of the computational burden involved.

After this short introduction, a multi-site model for rainfall generation is presented. Then the wet and dry characteristics are defined using the corresponding characteristics of the runs of monthly rainfall sequences once a truncation level is introduced. To provide relevant information on the rainfall distribution in the valley, a simple statistical analysis is carried out. Some of the descriptors of the distribution of monthly rainfall are later used to evaluate the appropriateness of the multi-site model. Finally, the wet and dry analysis is carried out using large samples of generated data in order to determine some important statistical descriptors of the wet and dry events at all the stations in that region.

II Multi-site Rainfall Generation Model

2.1 General Disaggregation Model

The general disaggregation model [Valencia and Schaake 1972] is of form:

$$Y = AX + BV \tag{1}$$

where Y is a k-vector of correlated random variables,
X is a z-vector of correlated random variables,
A is a $k \times z$ matrix of coefficients,
B is a $k \times k$ matrix of coefficients,
and V is a k-vector of independent standard normal random variables.

The roles of z and k will become clear later. All random variables are assumed to have zero means. The variables Y and X are adjusted to have zero means (by removing their respective original means).

The model preserves the first and the second moment (mean and standard deviation) regardless of the distribution of the random variables. In general, the way V is chosen will affect the conditional distribution of Y given X; if V is multivariate normally distributed, the conditional distribution is also multivariate normal.

In practice, vectors Y and X are used to contain the historical rainfall data needed to estimate the coefficient matrices A and B. Vector V is generated by using normal random variables. To estimate matrices A and B for yearly rainfall, vector Y consists of the present yearly data, while vector X consists of the previous yearly data. The scheme follows Matalas' model. To estimate matrices A and B for seasonal rainfall, vector Y consists of the seasonal data, and vector X consists of the yearly data. And, for monthly rainfall generation vectors Y and X consist of the monthly and the seasonal data, respectively.

2.2 Parameter Estimation

Let vectors Y and X have n observations respectively,

$$\underset{[z \times n]}{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ x_{z1} & x_{z2} & \cdots & x_{zn} \end{bmatrix}$$

$$\underset{[k \times n]}{Y} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1n} \\ y_{21} & y_{22} & \cdots & y_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots \\ y_{k1} & y_{k2} & \cdots & y_{kn} \end{bmatrix}$$

The variance and covariance matrices are estimated as follows:

$$S_{xx}=\frac{1}{n-1}[XX^T]$$
$$S_{yy}=\frac{1}{n-1}[YY^T] \qquad (2)$$
$$S_{yx}=\frac{1}{n-1}[YX^T]$$

where X^T denotes the transpose of matrix X.

(1) Estimation of Coefficient Matrix A

If both sides of eq. 1 are postmultiplied by the transpose of X, the result is

$$YX^T=A\ XX^T+B\ VX^T \qquad (3)$$

Eq. 3 yields the covariance matrix of YX^T as follows:

$$S_{yx}=A\ S_{xx}+B\ S_{vx} \qquad (4)$$

where S_{yx} is the covariance matrix of Y with X,
S_{xx} is the covariance matrix of X with itself,
and S_{vx} is the covariance matrix of V with X.

Since V is independent of X, $S_{vx}=0$, and therefore eq. 4 becomes

$$S_{yx}=A\ S_{xx} \qquad (5)$$

The coefficient matrix A is estimated by

$$A=S_{yx}\ S_{xx}^{-1} \qquad (6)$$

(2) Estimation of Matrix BB^T

Postmultiplying eq. 1 by Y^T gives

$$\begin{aligned}YY^T&=(AX+BV)(AX+BV)^T\\&=A\ XX^TA^T+A\ XV^TB^T\\&\quad+B\ VX^TA^T+B\ VV^TB^T\end{aligned} \qquad (7)$$

Eq. 7 yields the covariance matrix of YY^T as follows:

$$\begin{aligned}S_{yy}&=A\ S_{xx}A^T+A\ S_{xv}B^T\\&\quad+B\ S_{vx}A^T+B\ S_{vv}B^T\end{aligned} \qquad (8)$$

Since V and X are independent and V is assumed to consist of standard normal variables, $S_{xv}=S_{vx}=0$ and $S_{vv}=I$, where I is the identity matrix. Therefore, eq. 8 becomes

$$S_{yy}=A\ S_{xx}A^T+BB^T \qquad (9)$$

Using eq. 6 to substitute for A, eq. 9 becomes

$$\begin{aligned}S_{yy}&=(S_{yx}S_{xx}^{-1})S_{xx}(S_{yx}S_{xx}^{-1})^T+BB^T\\&=S_{yx}S_{xx}^{-1}S_{yx}^T+BB^T\end{aligned} \qquad (10)$$

The matrix BB^T is estimated by

$$BB^T=S_{yy}-S_{yx}S_{xx}^{-1}S_{yx}^T \qquad (11)$$

and BB^T is used to estimate the coefficient matrix B.

(3) Estimation of Coefficient Matrix B

The coefficient matrix B is not unique and there are presently two techniques available for estimating matrix B from BB^T. Matalas [1967] and Valencia and Schaake [1972] used principal component analysis. Young and Pisano [1968] estimated matrix B by assuming it to be lower triangular, and this technique is used in this study.

Defining $C=BB^T$, the elements of B can be determined using the following algorithm:

$$b_{ij}=0 \qquad \text{for } i<j \qquad (12)$$
$$b_{11}=c_{11} \qquad \text{for } i=j=1; \qquad (13)$$

the other elements of the first column of B are given by

$$b_{i1}=\frac{c_{i1}}{b_{11}}; \qquad (14)$$

the j th($j=2,3,\ldots,k$) diagonal element can be estimated by

$$b_{jj}=\sqrt{c_{jj}-\sum_{r=1}^{k-1}b_{jr}}\ ; \qquad (15)$$

the other elements are determined by

$$b_{ij}=c_{ij}-\sum_{r=1}^{j-1}\left(b_{ik}\frac{b_{jr}}{b_{jj}}\right) \qquad (16)$$

2.3 *Generation of Yearly Values*

The yearly rainfall generation model is based on the lag-one multivariate autoregressive process of Matalas [1967]. This model has proven adequate for representing stochastic hydrologic phenomena——e.g., streamflows or rainfall. The basic equation has the same form as eq. 1——viz.

$$X_{yt}=A_y X_{y,t-1}+B_y V_{yt} \tag{17}$$

where X_{yt} and $X_{y,t-1}$ are z-element vectors of the normalized yearly rainfall values at z stations, in year t and $t-1$, respectively;
A_y and B_y are $z\times z$ coefficient matrices of yearly rainfall values;
and V_{yt} is a z-element vector of standard normal random variables in year t.

Note that in this case, $k=z$, the number of stations involved.

After all the coefficient matrices have been estimated, the procedure used to generate yearly values is:

1. Initialize vector $X_{y,t-1}=0$;
2. Generate z-element vector V_{yt};
3. Generate z-element vector X_{yt} using eq. 17;
4. Update $X_{y,t-1}$, with value X_{yt};
5. Repeat steps 2, 3, and 4 until the desired number of years has been generated.

2.4 *Generation of Seasonal Values*

The generated yearly values are disaggregated into s seasonal values using the model of eq. 1 as follows:

$$X_{st}=A_s X_{yt}+B_s V_{st} \tag{18}$$

where X_{st} is a p-element vector of the normalized seasonal values of z stations in year t ($p=k=S\times z$, S : number of seasons used for a year),
X_{yt} is a z-element vector of the generated yearly values in year t,
A_s and B_s are $p\times z$ and $p\times p$ coefficient matrices of seasonal values,
and V_{st} is a p-element vector of standard normal random variables for season s and year t.

After all of the coefficient matrices have been estimated, the procedure used for generating seasonal values is as follows:

1. Generate p-element vector V_{st};
2. Generate p-element vector X_{st} using eq. 18;
3. Repeat steps 1 and 2 until the desired number of years of seasonal values has been generated.

2.5 *Generation of Monthly Values*

The generated seasonal values are disaggregated into monthly values using the model of eq. 1 as follows:

$$X_{mst}=A_{ms} X_{st}+B_{ms} V_{mst} \tag{19}$$

where X_{mst} is a q-element vector of the normalized monthly values at z stations, in season s, and year t ($q=12\times z$),
X_{st} is a z-element vector of the generated seasonal values at z stations, season s, and year t,
A_{ms} and B_{ms} are $q\times z$ and $q\times q$ coefficient matrices of monthly values at season s,
and V_{mst} is a q-element vector of stan-

dard normal random variables for month m, season s, and year t.

After all of the coefficient matrices have been estimated, the procedure used for generating monthly values is as follows:

1. Generate q-element vector V_{mst};
2. Generate q-element vector X_{mst}, using eq. 19;
3. Repeat steps 1 and 2 until the desired number of years of monthly values has been generated.

III Wet and Dry Characteristics

The theory of runs has gained popular use in connection with the analysis of wet and dry events. Generally, a run is defined as a sequence of observations of the same kind preceded and succeeded by one or more observations of a different kind. In stochastic hydrology, it is a sequence of upcrosses/downcrosses preceded and succeeded by at least a downcross/upcross.

Let $\{P_{ij}\}$ denote a sequence of monthly rainfall, $i=1,\ldots,n$ and $j=1,\ldots,12$ where n is the length of the sequence (in years).

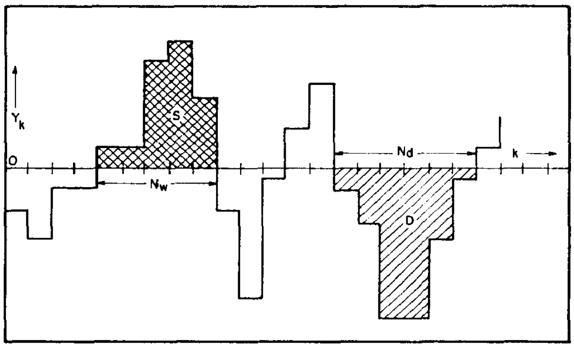

Fig. 1 Difinition Sketch of Durations of Wet (N_w) and Dry (N_d) Events ; and Magnitudes of Wet (S) and Dry (D) Events

Let $\bar{P}_j$ denote the mean of rainfall amounts in month j, and α denote a positive constant, then a new sequence $\{Y_k\}$ can be defined as follows:

$$Y_k=P_{ij}-\alpha\bar{P}_j,\ k=12(i-1)+j \tag{20}$$

A simple sketch of this sequence is shown in Fig. 1. The truncation level in this case is defined as $\alpha\bar{P}_j$ which varies with the months of the year, and completely determined by α. In practice α is around 1.0, because the demand or the level of water utilization is about the monthly mean for each month. With the definition given by eq. 20, the seasonal sequence of monthly rainfall amounts P_{ij} with varying truncation $\alpha\bar{P}_j$ is reduced to a simpler sequence $\{Y_k\}$ which is truncated at zero (Fig. 1). For this sequence, a *surplus* occurs when $Y_k>0$ and a *deficit* occurs when $Y_k\leq 0$. Correspondingly, the runs characteristics can be defined such as the positive run-length, N_w; the negative run-length, N_d; the positive run-sum, S, and the negative run-sum, D. In the context of wet and dry analysis, N_w represents the *duration of a wet event,* S the *magnitude* of that wet event, while N_d represents the *duration of a dry event* with corresponding *magnitude* D. The ratios S/N_w and D/N_d represent the *wet severity* and *dry severity*, respectively. With these definitions, the analysis of wet and dry characteristics is reduced to the determination of their distributions. Due to the difficulty involved in the mathematical derivation, a simulation was adopted in this study and the main purpose is to determine the first two descriptors, the mean and standard deviation of the distributions of each of these characteristics.

IV Historical Data Analysis and Model Evaluation

4.1 Region Selection and Data Collection

Daily rainfall data from Water Resources Region No. 2 (Cagayan Valley) in the northern part of the Philippines were gathered and used in this study. The choice of the region was made on the basis of the existing number of rainfall gaging stations and on the uniformity of climate conditions in the area.

Cagayan Valley, located in the northern portion of Luzon Island, is the second largest contiguous plain, next to the Central region, in the whole island. It has an approximate area of 34,500 km^2 and composed of six provinces namely, Cagayan, Isabela, Nueva Vizcaya, Kalinga-Apayao, Mountain Province and Quirino, and some parts of the neighboring provinces (Fig. 2). The major basin in the region is drained by the Cagayan River and its tributaries, and the smaller basins are drained by smaller rivers flowing into the Babuyan Channel in the north or the Pacific Ocean in the east.

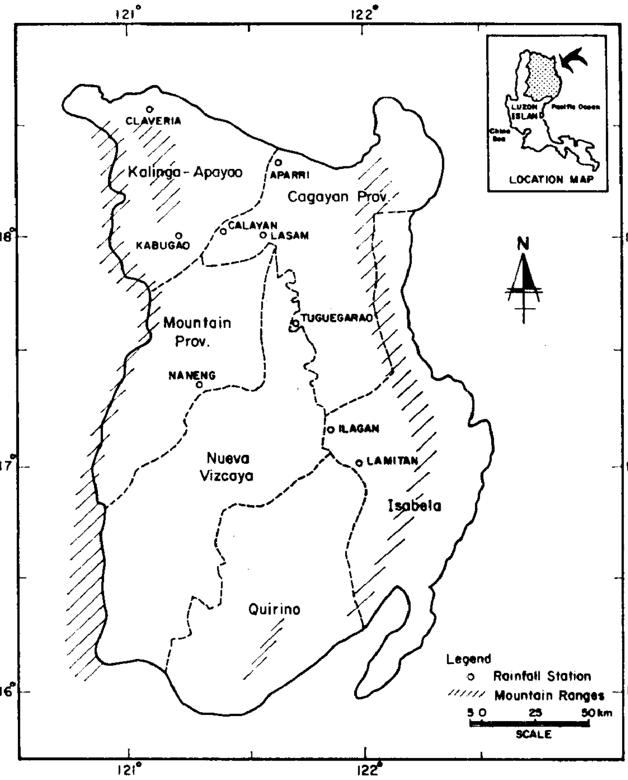

Fig. 2 Locations of Selected Rainfall Stations

The climate falls under the Type III climate zone which is generally characterized by no pronounced maximum rainfall period and a short dry period. It is dry between January to May and wet during the rest of the year. Unlike the Central and the Southern regions, it is not often visited by typhoons, and because of this it has relatively uniform climatic features throughout the year.

As of the 1976 survey [NWRC Report No. 19 1976] there are 52 existing rainfall gaging stations in the region. Out of these, 10 have more than 15 years length of record. This is shown in Table 1 which also contains some information about the other regions for comparison.

The rainfall gaging stations considered in the study were selected according to the following criteria:

(1) Long Length of Record

Analysis of hydrologic phenomenon or any other water resources study requires sufficiently long historical records of data so that the samples can closely represent the characteristics of the unknown population.

(2) Uniform Distribution in the Area

Sample points should always represent the area where they are derived. The region can only be properly represented when the gaging points are uniformly

Table 1 Rainfall Gaging Stations in the Philippines (after NWRC [1976])

No.	Water Resources Regions	Number of Stations Years of Record ≤5	6–10	11–15	16–20	21–30	>30	Total No. of Stations
I	Ilocos	3	7	0	0	7	0	17
II	Cagayan Valley	3	24	15	2	8	0	52
III	Central Luzon	40	35	2	3	12	0	92
IV	Southern Tagalog	12	18	1	0	9	0	40
V	Bicol	24	12	0	3	9	1	49
VI	Western Visayas	2	13	0	0	9	1	25
VII	Central Visayas	4	0	1	1	8	0	14
VIII	Eastern Visayas	5	8	3	2	0	0	18
IX	Southwestern Mindanao	4	3	0	0	3	0	10
X	Northern Mindanao	1	3	3	0	5	1	13
XI	Southeastern Mindanao	3	1	1	1	6	0	12
XII	Southern Mindanao	15	3	2	1	6	0	27
	Total	116	127	28	13	82	3	369

distributed spatially.

From the updated record of the Philippines Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), 11 gaging stations with not less than 20 years of records were available. However, only nine were selected because one is located in an island province and it is expected that its climatic regime will not be similar with the mainland, and another one is separated by a great distance from the cluster of the rest of stations and it was

Table 2 Selected Rainfall Stations and Their Length of Record (Taken from PAGASA [1981])

Station	Code	Locations Place	Lat. N.	Long. E.	Period of Record	Length of Record(yr)
1. Aparri	APARRI	Cagayan Prov.	16–29	120–45	1904–1940 1949–1978	67
2. Calayan	CALAYN	Cagayan Prov.	18–06	121–22	1949–1978	30
3. Claveria	CLVRIA	Kalinga-Apayao	18–37	121–05	1956–1975	20
4. Ilagan	ILAGAN	Isabela Prov.	17–08	121–50	1956–1978	23
5. Kabugao	KBUGAO	Kalinga-Apayao	18–02	121–11	1935–1940 1956–1976	27
6. Lamitan	LMITAN	Isabela Prov.	16–59	121–50	1956–1976	21
7. Lasam	LASAM	Cagayan Prov.	18–03	121–37	1956–1976	21
8. Naneng	NANENG	Kalinga-Apayao	17–24	121–06	1956–1977	22
9. Tuguegarao	TUGARA	Cagayan Prov.	17–37	121–42	1907–1940 1949–1980	66

suspected that its climatic regime will differ from the majority. The nine selected stations are listed in Table 2, together with relevant information. In Fig. 2 the geographical locations of the stations are shown.

It should be pointed that the length of records for all stations was made uniform during the simulation process because the data generator that was used required such. Twenty-year period, 1956–1975, was adopted since this is the longest available length common to all sites.

Like all other historical materials, the collected data are not free from missing values. Using the additional daily records gathered from other agencies and the field stations, missing data were filled (note that the original data were contained on magnetic tape). However, some records remained unfilled and some values were forever lost. Thus, data estimation was employed.

From the daily rainfall, total monthly values were initially computed to reduce the storage requirement. And then Stepwise Regression method following program BMDPAM of the Biomedical Computer Programs (BMDP) available at the Regional Computer Center, Asian Institute of Technology, was used to estimate the monthly missing records. About 42 missing values were computed and later filled to complete the required data set.

4.2 *Statistical Properties of Historical Data*

A statistical analysis of the historical data was carried out by first computing some of the important parameters. The mean ($\bar{X}$), standard deviation (STD), skewness coefficient (Cs) and the coefficient of variation (Cv) were determined for the annual, seasonal and monthly rainfall series. Shown in Table 3 are the values for these parameters for all stations. It is noted that annual means range from about 1,700 mm to about 4,200 mm, with Claveria having the maximum and Tuguegarao having the minimum. Annual rainfall values do not vary widely relative to their respective means as indicated by the annual Cv's of not more than 0.7 for all the stations. This implies that annual data tend to cluster towards their respective means. Moreover, it is observed that the annual Cs's are generally positive-valued, except for Lamitan and Naneng.

On the same table it is also obvious that there is considerable difference between season 1 (dry) and season 2 (wet) in terms of the means. This is affirmed by a lower rainfall amount from January to May or June compared to that in the remaining months of the year. These observations are thus consistent with the Type III climate classification of the region. It is noted also that the seasonal data have higher Cv values than their corresponding annual values at most stations. Understandably, seasonal data tend to vary more widely away from their means as compared with the annual values. With these values it can be inferred that the climate at the stations is distinctively dry during the first five (or six) months and wet during the rest of the year.

It is observed that the monthly rainfall data tend to scatter from the mean as indicated by high values of Cv. Further-

Table 3 Some Important Statistics of Historical Data

Station		X̄ (mm)	STD (mm)	Cv	Cs
1. Aparri					
Annual		2256.7	507.4	0.224	0.19
Season 1		606.1	233.2	0.384	1.13
Season 2		1650.6	452.3	0.274	0.28
Monthly:	J	135.4	90.2	0.666	1.25
	F	82.6	65.2	0.790	0.95
	M	55.8	46.1	0.827	1.07
	A	44.1	50.0	1.130	2.09
	M	109.7	83.2	0.757	1.31
	J	178.5	135.9	0.761	2.23
	J	195.5	143.6	0.734	1.14
	A	237.5	140.3	0.591	0.94
	S	286.8	177.8	0.619	1.92
	O	360.3	187.4	0.520	1.25
	N	359.8	248.6	0.691	1.19
	D	210.5	116.6	0.555	0.66
2. Calayan					
Annual		2739.1	552.0	0.201	0.51
Season 1		708.9	197.0	0.277	−0.12
Season 2		2030.1	580.5	0.285	0.50
Monthly:	J	186.8	87.9	0.470	0.38
	F	123.2	78.7	0.638	1.69
	M	68.9	48.6	0.705	1.86
	A	41.6	32.1	0.772	1.09
	M	98.3	93.8	0.954	1.27
	J	190.0	125.0	0.658	0.49
	J	272.7	247.7	0.908	1.07
	A	296.6	190.0	0.640	1.15
	S	325.2	142.0	0.436	1.22
	O	363.4	216.9	0.596	0.95
	N	409.6	268.1	0.654	0.93
	D	362.3	203.2	0.560	0.96
3. Claveria					
Annual		4209.7	780.9	0.185	0.38
Season 1		1564.2	452.2	0.289	0.89
Season 2		2645.5	660.1	0.249	0.44
Monthly:	J	515.4	212.9	0.413	0.66
	F	305.8	163.9	0.536	1.32
	M	190.2	104.9	0.551	0.63
	A	146.4	83.9	0.573	0.43
	M	164.8	119.6	0.725	0.62
	J	241.2	141.0	0.584	0.49
	J	271.2	212.3	0.783	1.34
	A	297.5	188.8	0.684	0.52
	S	278.9	102.8	0.368	1.16
	O	411.1	204.0	0.496	0.48
	N	655.9	375.1	0.571	1.13
	D	730.8	292.2	0.399	0.08
4. Ilagan					
Annual		1949.2	563.3	0.288	0.71
Season 1		488.7	192.1	0.393	1.03
Season 2		1460.5	505.6	0.347	0.34
Monthly:	J	62.4	56.3	0.902	2.15
	F	35.7	34.8	0.972	2.21
	M	42.6	36.2	0.850	1.34
	A	52.8	54.0	1.023	1.72
	M	121.9	95.8	0.786	1.21
	J	173.1	104.4	0.603	0.51
	J	159.2	86.8	0.544	1.00
	A	219.0	152.1	0.694	2.49
	S	209.7	72.4	0.345	−1.21
	O	332.8	239.0	0.718	1.05
	N	350.3	256.1	0.731	0.78
	D	189.3	138.6	0.732	0.71
5. Kabugao					
Annual		2577.7	472.7	0.183	0.78
Season 1		669.2	170.8	0.255	−0.26
Season 2		1908.4	527.6	0.286	0.49
Monthly:	J	76.2	45.2	0.578	0.77
	F	43.1	55.7	1.290	3.91
	M	55.6	49.1	0.883	1.76
	A	64.0	45.0	0.703	0.63
	M	198.7	107.6	0.541	0.14
	J	229.4	65.1	0.284	0.15
	J	301.4	157.4	0.522	0.88
	A	264.0	102.7	0.384	0.11
	S	255.5	109.0	0.427	0.98
	O	428.4	198.7	0.463	−0.58
	N	455.6	330.3	0.724	0.91
	D	200.4	116.3	0.580	−0.58
6. Lamitan					
Annual		1910.6	520.9	0.272	−0.54
Season 1		736.9	221.9	0.301	−0.16
Season 2		1173.6	367.5	0.313	−0.46
Monthly:	J	82.5	52.8	0.639	0.33
	F	58.2	45.9	0.789	1.14

Station	$\bar{X}$ (mm)	STD (mm)	Cv	Cs
M	57.5	40.7	0.707	1.34
A	93.5	68.2	0.729	0.85
M	210.0	119.5	0.521	1.92
J	235.0	105.8	0.450	0.49
J	232.9	97.5	0.418	−0.39
A	247.3	93.7	0.378	0.66
S	205.5	87.1	0.424	−0.06
O	246.4	128.4	0.521	0.74
N	137.0	82.1	0.599	0.93
D	104.2	86.2	0.827	1.86
7. Lasam				
Annual	1923.6	1119.5	0.582	1.32
Season 1	743.1	545.4	0.734	1.48
Season 2	1180.5	770.9	0.653	1.67
Monthly: J	78.8	51.2	0.650	0.44
F	58.0	47.1	0.812	1.13
M	58.3	41.7	0.715	1.37
A	95.9	69.2	0.722	0.77
M	210.7	112.3	0.533	1.87
J	241.4	104.4	0.432	0.45
J	232.3	100.0	0.430	−0.36
A	248.5	93.1	0.375	0.61
S	208.5	88.5	0.424	−0.15
O	246.6	131.8	0.534	0.72
N	140.7	82.5	0.586	0.86
D	103.9	88.5	0.851	1.84
8. Naneng				
Annual	2125.1	556.9	0.262	−0.34
Season 1	697.4	253.3	0.363	0.35
Season 2	1427.7	386.0	0.270	−0.60
Monthly: J	44.2	39.3	0.887	1.61
F	33.1	61.1	1.847	3.38
M	57.0	48.7	0.854	1.34
A	82.3	80.8	0.739	0.34
M	199.8	158.7	0.793	1.76
J	280.7	118.7	0.422	0.10
J	272.9	111.4	0.408	0.40
A	327.6	106.0	0.323	0.10
S	262.7	109.1	0.415	0.86
O	258.7	170.5	0.659	0.32
N	202.6	150.7	0.743	0.80
D	103.0	150.7	1.461	1.03

Station	$\bar{X}$ (mm)	STD (mm)	Cv	Cs
9. Tuguegarao				
Annual	1719.6	390.5	0.227	0.29
Season 1	420.9	139.3	0.331	0.20
Season 2	1298.7	379.3	0.292	0.53
Monthly: J	28.0	28.6	1.020	1.51
F	20.8	25.0	1.198	1.39
M	30.0	26.9	0.895	1.56
A	58.2	59.8	1.027	1.59
M	128.9	92.4	0.716	1.72
J	154.7	79.8	0.516	1.04
J	234.9	122.0	0.519	0.81
A	239.7	165.7	0.691	1.43
S	216.9	135.6	0.625	1.47
O	220.4	153.5	0.696	0.66
N	259.5	203.4	0.783	1.16
D	127.1	121.5	0.956	1.68

more, most monthly Cs values are quite high, suggesting that monthly rainfall sequences should be fitted by non-normal distributions. Fitting monthly sequences at each station was performed for the lognormal, two-parameter gamma and the leakage law distributions [Phien *et al.* 1980]. Employing the Kolmogorov-Smirnov goodness-of-fit test at the 5% significance level, it was found that the lognormal and the two-parameter gamma distributions are acceptable. This finding is a confirmation of the previous statement that the monthly data are not normally distributed. Examples of the fitting process for stations Aparri and Tuguegarao are given in Table 4 where the parameters of the distribution and the corresponding computed DELTA (Kolmogorov-Smirnov statistic) are also provided. Note that when the computed DELTA falls into the critical region, the fitting process is unsuccessful.

Table 4 Examples of Fitting Monthly Rainfall Data

Station	Max.	Min.	Lognormal (a)			Gamma (b)		
Aparri			XMU	SIGMA	DELTA*	ALPHA	BETA	DELTA*
Jan.	464.7	0.0	—	—	—	—	—	—
Feb.	259.4	0.0	—	—	—	—	—	—
Mar.	196.7	0.7	3.761	0.722	0.124	1.461	38.195	0.241**
Apr.	242.9	0.0	—	—	—	—	—	—
May	451.1	1.2	4.471	0.674	0.116	1.740	63.067	0.069
Jun.	811.8	20.7	4.956	0.676	0.041	1.725	103.469	0.069
Jul.	695.1	6.6	5.060	0.657	0.127	1.854	105.459	0.062
Aug.	615.5	17.5	5.321	0.547	0.088	2.866	82.874	0.070
Sept.	1132.5	25.4	5.496	0.570	0.079	2.602	110.232	0.066
Oct.	1136.4	62.7	5.767	0.489	0.106	3.695	97.515	0.078
Nov.	1088.8	33.5	5.691	0.625	0.107	2.095	171.756	0.071
Dec.	546.9	18.2	5.215	0.519	0.098	3.241	64.972	0.071
Tuguegarao								
Jan.	121.2	0.0	—	—	—	—	—	—
Feb.	103.3	0.0	—	—	—	—	—	—
Mar.	134.7	0.0	—	—	—	—	—	—
Apr.	249.9	0.0	—	—	—	—	—	—
May	482.1	0.0	—	—	—	—	—	—
Jun.	422.1	0.0	—	—	—	—	—	—
Jul.	589.7	47.3	5.340	0.489	0.095	3.704	63.436	0.057
Aug.	812.9	28.2	5.284	0.625	0.079	2.093	114.587	0.104
Sept.	703.9	19.2	5.214	0.574	0.071	2.558	84.791	0.071
Oct.	657.3	0.0	—	—	—	—	—	—
Nov.	908.8	0.0	—	—	—	—	—	—
Dec.	655.3	0.0	—	—	—	—	—	—

* Computed Kolmogorov-Smirnov Statistic. Critical value at 5% significance level is DELTA=0.172.
** Fitting process failed
— Not applicable
(a) XMU & SIGMA: Parameters of the lognormal distribution
(b) ALPHA & BETA: Parameters of the gamma distribution

However, it should be emphasized that the conclusion drawn in this fitting is true only for those series without or with very minimal zero values. For those sequences having numerous zero records, their probability distributions remain to be found since the lognormal and the gamma functions are not suitable. It should also be noted that the above analysis was undertaken for the uncut observed sequences, not for those in the adopted period (1956–1975).

4.3 *Comparison of Generated Data and Historical Values*

Using the presented multi-site data generation model, 800-year monthly rainfall values were generated for all the nine stations. The means, standard deviations,

Table 5 Statistics of Generated Sequences and Their Historical Counterparts for Aparri and Calayan

Station	Month	Statistics of Monthly Generated Value				Statistics of Monthly Historical Data			
		Mean	STD	Cs	Cv	Mean	STD	Cs	Cv
Aparri	Jan.	167.6	130.4	1.43	0.76	161.8	103.4	0.66	0.64
	Feb.	86.5	55.4	1.10	0.64	89.5	65.3	0.81	0.73
	Mar.	48.7	49.7	1.77	1.02	43.5	39.0	1.30	0.90
	Apr.	50.7	50.3	1.76	0.99	50.7	56.2	2.33	1.11
	May	81.0	51.3	1.04	0.63	58.1	73.4	0.82	0.83
	Jun.	177.2	99.0	0.96	0.56	195.4	186.5	2.15	0.95
	Jul.	220.6	210.8	1.88	0.96	198.4	191.9	1.50	0.98
	Aug.	253.3	208.1	1.30	0.82	237.3	168.9	0.93	0.71
	Sept.	309.5	155.7	0.87	0.50	310.1	229.5	2.57	0.74
	Oct.	314.2	98.2	0.41	0.31	337.7	161.8	−0.02	0.48
	Nov.	414.3	241.5	0.96	0.58	444.9	345.3	0.72	0.78
	Dec.	192.9	93.6	0.70	0.46	198.2	93.3	0.15	0.47
Calayan	Jan.	179.1	75.4	0.49	0.42	182.5	85.5	0.39	0.47
	Feb.	122.2	70.2	1.07	0.57	118.1	76.4	2.37	0.65
	Mar.	78.0	53.4	1.03	0.68	71.9	37.5	0.36	0.52
	Apr.	48.9	45.7	1.79	0.94	41.3	35.5	1.21	0.86
	May	78.8	47.3	0.85	0.60	95.8	99.9	1.32	1.04
	Jun.	163.8	90.5	0.86	0.55	177.6	132.3	0.68	0.74
	Jul.	346.2	376.1	1.86	1.09	289.0	281.0	0.94	0.97
	Aug.	233.6	123.6	0.93	0.53	251.2	161.4	0.62	0.64
	Sept.	336.9	131.6	0.44	0.39	333.8	165.1	1.04	0.49
	Oct.	344.9	171.1	0.84	0.50	362.4	242.7	1.06	0.67
	Nov.	364.6	295.7	1.15	0.77	360.6	265.2	0.93	0.74
	Dec.	333.5	94.5	0.33	0.28	349.3	161.7	0.40	0.46

Table 6 Percentage of Times Accepted in the Mann-Whitney U-test at 5% Significance Level

Station	Month											
	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Aparri	100.0	100.0	67.5	80.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calayan	100.0	100.0	100.0	75.0	100.0	100.0	77.5	100.0	100.0	100.0	100.0	100.0
Claveria	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Ilagan	100.0	100.0	92.5	90.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Kabugao	100.0	100.0	97.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Lamitan	37.5	17.5	40.0	30.0	87.5	100.0	100.0	97.5	97.5	92.5	100.0	100.0
Lasam	100.0	90.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Naneng	97.5	57.5	100.0	97.5	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Tuguegarao	90.0	30.0	67.5	75.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	95.0

skewness coefficients and coefficients of variation were computed. Typical results are collected in Table 5 for the first two stations, i.e., Aparri and Calayan. Through visual inspection, it is apparent that these parameters of the generated data closely resemble that of the historical values, most especially the means and the standard deviations. This implies that the model preserves these two parameters. Although the model is not intended to reproduce the skewness coefficient of the historical data, the computed results were quite good in most cases. Moreover, a Mann-Whitney test [Gibbons 1971] indicated that there is a very high percentage that the generated sequences at a station have the same distributions as those of the historical data, as evidenced from Table 6. Thus the generated data are ready for use in the following wet and dry analysis.

The parameters of the historical data shown in Table 5 were computed at uniform length of 20-year records. These values are not similar with those previously presented because of the difference in sample sizes employed. It should be noted that for the wet and dry characteristics to be reliably estimated, the generated data should have a large sample. A size of 800 years was selected as a compromise between the computer time and the accuracy required.

V Wet and Dry Analysis

5.1 *Magnitudes, Durations and Intensities of Wet and Dry Events*

(1) Magnitudes as Indicated by the Run-sums

Coupled with the multivariate generation of rainfall depths is the runs theory to analyze the wet and dry conditions in the region. Run-lengths, run-sums and run-intensities are used in order to describe the properties of wet/dry events.

The magnitudes (indicated by the run-sums) of wet and dry events for all the stations at varying truncation level were computed and shown in Tables 7 and 8, respectively. Evidently, the magnitude in terms of the mean of wet event or the

Table 7 Magnitude of Wet Event

Station	Mean (mm)					Standard Deviation (mm)				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Aparri	274.9	229.4	201.0	178.9	164.5	378.1	323.8	286.8	259.3	241.2
Calayan	339.2	271.3	232.1	208.8	193.5	447.5	379.3	333.0	298.2	280.9
Claveria	437.7	321.0	251.7	213.4	187.2	545.1	418.4	332.0	278.8	236.2
Ilagan	252.9	203.7	172.5	152.3	139.8	379.3	320.5	277.9	251.3	232.5
Kabugao	261.3	198.1	156.5	130.3	116.6	366.7	296.8	245.4	205.7	180.8
Lamitan	189.2	168.7	154.8	143.3	132.1	202.8	276.7	257.7	242.9	228.8
Lasam	229.7	171.5	137.0	110.6	94.0	366.5	282.2	229.4	187.4	158.5
Naneng	245.5	188.2	149.1	120.2	100.5	343.2	265.2	202.1	159.4	132.8
Tuguegarao	165.1	136.2	116.8	103.2	92.4	214.0	180.2	156.7	136.6	123.4

Note: (1)–(5) correspond to $\alpha=0.8$, 0.9, 1.0, 1.1 and 1.2, respectively.

Table 8 Magnitude of Dry Event

Station	Mean (mm)					Standard Deviation (mm)				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Aparri	120.2	159.2	214.7	285.6	382.7	128.4	173.3	241.2	320.8	423.0
Calayan	131.1	168.7	225.8	308.5	421.3	140.3	185.5	251.8	242.6	459.6
Claveria	145.2	196.4	276.1	405.6	595.5	164.9	230.6	321.1	470.4	686.2
Ilagan	102.9	137.6	187.5	258.8	361.6	134.4	175.8	230.9	307.7	418.4
Kabugao	87.7	124.2	176.8	256.3	385.2	120.4	166.3	227.7	309.4	441.9
Lamitan	138.5	175.4	222.9	280.6	345.9	172.8	214.0	266.3	330.4	296.3
Lasam	71.9	100.8	146.2	207.7	301.8	103.6	147.0	214.0	308.1	428.3
Naneng	89.2	126.5	180.0	253.6	361.6	103.3	147.6	224.1	339.4	494.7
Tuguegarao	87.8	117.8	158.4	212.6	281.4	102.7	136.3	177.5	229.5	295.2

Note: (1)–(5) correspond to $\alpha=0.8$, 0.9, 1.0, 1.1 and 1.2, respectively.

amount of water surplus decreases as the truncation level goes higher, whereas that of dry event or the amount of water deficit behaves oppositely. This is understandable since when the truncation level goes higher, less surplus amounts and more deficits are obtained in the series. At truncation level corresponding to $\alpha=0.8$, the surplus at any station ranges from 165 mm to about 440 mm. At 0.9 level it is between 136 mm and 321; at 1.0 level, it is about 116 mm to 251 mm; at 1.1 truncation level, it is from 103 mm to 213 mm; and lastly at 1.2, it is between 92 mm and 187 mm. In most cases, Claveria has the maximum amount while Tuguegarao has the least. Furthermore, it is noted that the computed standard deviations are generally greater than their respective means which indicate that the surplus event tends to scatter away from the central value.

On the other hand, the amount of deficits (Table 8) ranges from 71 mm to about 145 mm at 0.8 truncation level. Progressively, it is from 100 mm to 196 mm at 0.9 level; about 146 mm to 276 mm at 1.0 truncation level; between 207 mm and 405 mm at 1.1; and lastly, it varies from 281 mm to 595 mm at 1.2. Claveria still contains the maximum deficits while Lasam exhibits the minimum except at 1.2 truncation level which goes to Tuguegarao. Like the surplus, deficit event varies considerably away from their respective means as indicated by higher values of the standard deviation than those of the mean.

From the results of the two events, together, it can be said that maximum surplus amount exists at Claveria while conjunctively, maximum deficit amount may also be found at this point. Also, minimum magnitude of surplus stems from Tuguegarao while the least magnitude of deficit may be located in Lasam.

(2) Durations as Indicated by the Run-lengths

The durations of wet and dry events as described by the corresponding run-lengths at different truncation levels were computed. In all levels of truncation, it can be observed that wet event (Table 9) occurred at the range of one and half months to about

Table 9 Duration of Wet Event

Station	Mean (month)					Standard Deviation (month)				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Aparri	2.3	2.0	1.8	1.6	1.5	2.0	1.6	1.4	1.2	1.0
Calayan	2.6	2.2	1.9	1.7	1.6	2.3	1.8	1.5	1.2	1.0
Claveria	2.9	2.3	1.9	1.6	1.5	2.5	1.9	1.4	1.1	0.8
Ilagan	2.7	2.3	2.0	1.8	1.7	2.4	1.9	1.5	1.2	1.1
Kabugao	2.7	2.2	1.9	1.6	1.5	2.2	1.7	1.4	1.1	0.9
Lamitan	2.3	2.1	2.0	1.9	1.8	2.0	1.8	1.6	1.4	1.3
Lasam	3.2	2.6	2.2	1.9	1.7	3.4	2.6	2.1	1.7	1.4
Naneng	3.0	2.5	2.2	1.9	1.7	3.0	2.3	1.8	1.4	1.2
Tuguegarao	2.1	1.8	1.6	1.5	1.4	1.6	1.2	1.0	0.9	0.7

Note: (1)–(5) correspond to $\alpha=0.8$, 0.9, 1.0, 1.1 and 1.2, respectively.

three months. The longest wet duration frequently occurs at Lasam and/or Naneng while the shortest happens in Tuguegarao. Also, it is noted that the standard deviation has lower values than that of the respective mean; this implies that the durations tend to cluster towards the central value and thus, they are less scattered.

The durations of dry event at varying truncation level were also evaluated. The occurrence of this event ranges from nearly two months to about four and half months (Table 10). The longest duration can be found in Lamitan while the shortest cannot be spatially specified since the minimum duration varies from station to station when the truncation level changes. Like in the wet event, the duration of dry event tends to occur nearer the mean as indicated by lower standard deviations than the corresponding means. This finding, however, is different from that of the magnitudes of the events.

Comparing the two events, it is very clear that dry events tend to last longer than wet events for about one month more. As

Table 10 Duration of Dry Event

Station	Mean (month)					Standard Deviation (month)				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Aparri	2.0	2.2	2.6	3.1	3.6	1.5	1.8	2.3	2.8	3.4
Calayan	2.0	2.2	2.6	3.1	3.8	1.4	1.7	2.2	2.8	3.6
Claveria	1.7	2.0	2.4	3.1	4.0	1.1	1.6	2.1	2.9	3.8
Ilagan	2.1	2.4	2.9	3.5	4.3	1.6	2.0	2.5	3.1	4.1
Kabugao	1.7	2.1	2.5	3.2	4.1	1.1	1.5	2.0	2.6	3.7
Lamitan	3.0	3.3	3.7	4.2	4.6	2.6	2.9	3.5	3.9	4.4
Lasam	2.0	2.4	2.9	3.5	4.4	1.8	2.3	3.1	4.0	5.1
Naneng	2.2	2.6	3.1	3.7	4.6	1.7	2.1	2.9	3.9	5.1
Tuguegarao	2.1	2.3	2.7	3.1	3.6	1.5	1.8	2.2	2.6	3.1

Note: (1)–(5) correspond to $\alpha=0.8$, 0.9, 1.0, 1.1 and 1.2, respectively.

mentioned, long duration of wet condition occurred at Lasam and/or Naneng while that of dry condition was found in Lamitan. Lastly the shortest wet event occurred in Tuguegarao while its dry counterpart cannot be specified to any of the gaging points.

(3) Severity as Indicated by the Run-intensities

Severity of an event is the extent of occurrence in terms of magnitude per unit of time. In this case, severity of a wet/dry event indicated by the respective run-intensities is the amount of surplus/deficit in mm per month.

For all levels of truncation, the severity or intensity of wet events in terms of the mean ranges from 46 mm/month to about 135 mm/month. Extreme severe condition is noted to be located in Claveria, while the least severe condition is found in Lasam. The values decrease with increasing level of truncation, and in general, the deviation from the mean is low as can be taken from a value of near unity for the ratio of standard deviation and mean values. For the dry events, the results are not very different. Mean intensities range from 32 mm/month to about 135 mm/month at all levels of truncation. From the range, Claveria contributes the maximum while Lasam has the minimum value. Like their wet counterparts, dry intensities have relatively lower deviations from the mean as seen from a value of less than unity of the coefficient of variation.

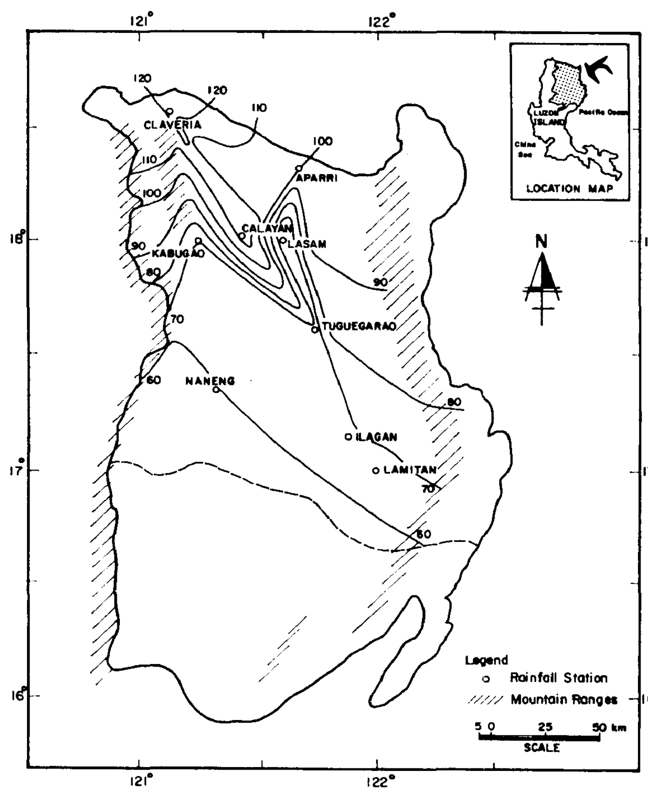

Fig. 3 Isolines of Water Surplus in mm/month with respect to Monthly Mean ($\alpha=1.0$)

Simplified regional water map for both wet and dry conditions can be drawn from the computed intensities. Isolines of wet event indicate the areal distribution of water surplus in the region, while isolines of dry event describe the distribution of deficit amounts. It is distinct from the surplus maps in all of the truncation levels that maximum intensity is at Claveria and gradually decreasing towards the area of Calayan and Kabugao. Then from Calayan, there is an abrupt decrease in intensity until the minimum at Lasam area is reached. Minimum areal intensity is obviously extended up to the areas south of the region. Also, the areal recession of the surplus becomes greater as the truncation value increases as indicated by denser isolines for the higher truncation levels. A typical map is shown in Fig. 3 for $\alpha=1.0$.

The same pattern is also true for the dry condition as clearly seen from inspection of the water deficit maps. Maximum deficit intensity is found in the area of Claveria and decreases gradually towards Calayan until the minimum is reached at the periphery of Lasam. Receding deficit intensity continues down to the portions south of Lasam. A pattern of areal deficit is then formed, which is a continuous descent from the northern part going to the southern portions. A typical case is shown in Fig. 4 for $\alpha=1.0$. Furthermore, the isolines become denser with the increasing truncation level. However, compared with the surplus maps, the deficit isolines tend to be less dense hence, there is no abrupt decrease in deficit intensity.

It should be clear from these maps that the area of interest is the northern part of the region since this is where the gaging points are located. Dashed lines drawn on the maps delineate this area from the rest of the region.

5.2 *Probabilities of Designated Durations of Events*

The likelihood of occurrence of some possible durations of wet and dry events were also determined. Durations of one-, two-, three-, and four- (and above) months were used as the desig-

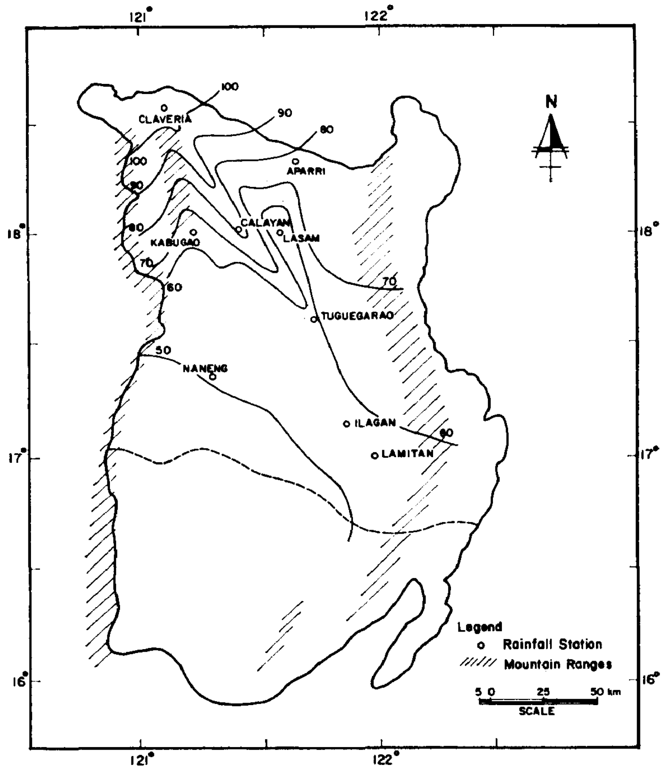

Fig. 4 Isolines of Water Deficit in mm/month with respect to Monthly Mean ($\alpha=1.0$)

Table 11 Probabilities of Designated Durations of Wet and Dry Events

Event	Station	1-month	2-month	3-month	≥4-month
Wet	Aparri	0.641	0.141	0.097	0.121
	Calayan	0.609	0.144	0.099	0.148
	Ilagan	0.529	0.205	0.142	0.124
	Kabugao	0.592	0.194	0.091	0.123
	Lamitan	0.558	0.200	0.107	0.135
	Lasam	0.540	0.203	0.087	0.170
	Naneng	0.494	0.251	0.109	0.146
	Tuguegarao	0.655	0.190	0.086	0.069
Dry	Aparri	0.480	0.161	0.089	0.270
	Calayan	0.466	0.164	0.115	0.255
	Claveria	0.449	0.211	0.142	0.198
	Ilagan	0.374	0.205	0.130	0.291
	Kabugao	0.425	0.218	0.125	0.232
	Lamitan	0.340	0.176	0.120	0.364
	Lasam	0.460	0.208	0.092	0.240
	Naneng	0.343	0.243	0.133	0.281
	Tuguegarao	0.417	0.187	0.141	0.255

nated periods and their probabilities computed.

From computed probabilities at all truncation levels, it is readily seen that the probabilities decrease as the duration becomes longer (see Table 11 for $\alpha=1.0$). In most cases, the first three months accounts about 60 to 80% of the total probabilities of possible durations while excess is carried by the longer durations. The one-month duration has the highest probability which is about 30 to 60% or approximately one occurrence in every 1.5 to 3.0 months. This is followed by the two-month period with probability range of 10% to 25% or once in 4 to 10 months. Last is the three-month duration with probabilities between 7% and 15% or one occurrence in every 6 months to 14 months.

5.3 *Critical Wet and Dry Conditions*

Extreme conditions like flood for the wet case and drought for the dry case are very critical phenomena. Their occurrence brings damages and sometimes a catastrophe to the affected area. In this regard, their magnitudes, durations and probabilities were determined using the corresponding critical conditions of the properties of runs. The magnitudes of extreme wet and dry events together with their durations in months and the probabilities for the given truncation levels were computed. At 0.8 truncation level, Claveria with magnitude of 4,877.7 mm has the maximum surplus value and with duration of 19 months, while Tuguegarao the minimum amount which is 1,764.5 mm with 9 months period. On the other hand, the largest deficit occurs at Claveria also, with magnitude of 1,487.6 mm and duration of 6 months while the minimum value is found in Tuguegarao with an amount of 783.5 mm and a period of 11 months.

In the case of 0.9 and 1.0 truncation levels, Claveria still has the highest surplus amounts with values of 4,235.8 mm and 2,934.3 mm, respectively. For the next higher truncation levels, 1.1 and 1.2, Lamitan and Calayan have the highest magnitudes. For the minimum value, Tuguegarao still gives the lowest magnitude in these

Table 12 Critical Wet and Dry Conditions at $\alpha=1.0$

Station	Extreme Wet Event			Extreme Dry Event		
	Magnitude (mm)	Duration (month)	Probability	Magnitude (mm)	Duration (month)	Probability
Aparri	2561. 9	3	<0. 001	1254. 0	6	<0. 001
Calayan	2894. 2	10	<0. 001	1513. 8	14	<0. 001
Claveria	2934. 3	6	<0. 001	2563. 1	10	<0. 001
Ilagan	2499. 9	3	0. 001	1679. 4	18	0. 001
Kabugao	2246. 4	6	<0. 001	1815. 3	16	<0. 001
Lamitan	2902. 9	5	0. 001	1800. 6	26	0. 001
Lasam	2264. 0	15	0. 001	1686. 4	22	0. 001
Naneng	1917. 6	20	0. 001	2104. 2	29	0. 001
Tuguegarao	1427. 6	7	<0. 001	1118. 2	11	<0. 001

higher truncation levels. Likewise, in the deficit condition, Claveria and Tuguegarao have the maximum and the minimum amounts, respectively, for all the higher truncations. Typical results are collected in Table 12 for $\alpha=1.0$.

In general, the probabilities of these extreme values for all levels of truncation are about 0.1% or less which is equivalent to one possible occurrence in 1,000 years. This probability value is practically negligible and thus, the likelihood of occurrences of these critical phenomena is very nil. It is noticeable also that the extreme dry events tend to have longer durations than their wet counterparts as evidenced by values between 5 to 47 months for the former and between 3 to 21 months for the latter in all levels of truncation.

Remarks

(1) Due to the truncation level being expressed as a portion of the monthly mean, it appears that larger amounts of water surplus occur at almost the same place as larger amounts of water deficit. This result may seem to be strange, but it is obvious from the theory of runs. However, their occurrence does not take place at the same time.

(2) The truncation level employed in this study was intended to reflect the common practice of utilizing more water whenever it is available. The situation would turn out to be different if the same truncation level is used at all stations.

Summary and Conclusions

In this study, a statistical analysis of wet and dry events for the Cagayan Valley in the Philippines was carried out by using the theory of runs along with a multi-site data generation scheme. Besides this analysis, some important characteristics of the rainfall distribution in this Valley were also investigated. From the results, the following conclusions were drawn.

(1) From January to May or June (Dry season), monthly rainfall amounts were very small compared to the remaining months of the year (Wet season).

(2) Rainfall amounts in these two seasons fluctuated from their respective means more than annual values.

(3) Rainfall in wet months (containing no zero values) were fitted by the lognormal and gamma distributions.

(4) The multi-site model can produce monthly rainfall sequences which resemble the historical data in terms of the mean and standard deviation.

(5) The largest magnitude of the wet event frequently occurred at Claveria while the smallest magnitude occurred at Tuguegarao.

(6) The magnitudes of the wet event tended to scatter away from their mean.

(7) The maximum deficit was found to occur at Claveria, while the minimum deficit was frequently located at Lasam.

(8) In most cases, the longest wet duration was found at Lasam or Naneng while the shortest happenned at Tuguegarao.

(9) Wet periods did not fluctuate so much from their mean.

(10) The longest dry duration was found at Lamitan, while the shortest varied from station to station depending

upon the truncation level.

(11) Intensity of surplus water was located at Claveria and gradually decreased towards the area of Calayan and Kabugao. Small intensity extended to the areas in the South of the region.

(12) Intensity of deficit water decreased from Claveria towards Calayan and the South.

The results obtained are related to the truncation level selected and would be very useful in the evaluation of the availability of rain water for agricultural development in the Cagayan Valley.

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